Industry Canada Industrie Canada

Working Paper Series / Collection Documents de travail

THE IMPACT OF FOREIGN OWNERSHIP ON AGGREGATE R&D INTENSITY: A CRITICAL REVIEW OF THE EMPIRICAL EVIDENCE

Donald McFetridge
Carleton University

Working Paper 2006-03

Canada

The Micro-Economic Policy Analysis Branch's Working Paper Series is intended as a means of diffusing research findings from Industry Canada projects for discussion and comment.

Working Papers are circulated in the language in which they were written. The papers reflect the views of the authors and no responsibility for them should be attributed to Industry Canada or the federal government. Comments on the papers are invited and may be sent directly to the authors.

La série Documents de travail de la Direction générale de l'analyse de la politique micro-économique se veut un moyen de diffuser les résultats des recherches issues des projets d'Industrie Canada dans le but de favoriser la discussion et la réception d'observations.

Les documents de travail sont diffusés dans la langue dans laquelle ils ont été écrits. Les opinions qui y sont exprimées sont celles des auteurs et n'engagent pas Industrie Canada ou le gouvernement fédéral. Le lecteur est prié de faire part de ses commentaires aux auteurs.

Working Paper Series / Collection Documents de travail

THE IMPACT OF FOREIGN OWNERSHIP ON AGGREGATE R&D INTENSITY: A CRITICAL REVIEW OF THE EMPIRICAL EVIDENCE

Donald McFetridge
Carleton University

Working Paper 2006-03

IC 60029

To obtain copies of documents published under the Working Paper Series, please visit : http://strategis.ic.gc.ca/epic/internet/ineas-aes.nsf/en/h_rao1967e.html or contact:

Publications Coordinator
Micro-Economic Policy and Analysis
Industry Canada
10th Floor, East Tower
235 Queen Street
Ottawa, Ontario K1A 0H5

Tel.: (613) 952-6411; Fax.: (613) 991-1261
E-mail: mepa.apme@ic.gc.ca

Pour obtenir des exemplaires des documents publiés dans la collection des documents de travail, cliquer sur http://strategis.ic.gc.ca/epic/internet/ineas-aes.nsf/fr/h_rao1967f.html ou s'adresser à :

Coordinatrice des publications
Analyse de la politique micro-économique
Industrie Canada
10e étage, tour Est
235, rue Queen
Ottawa (Ontario) K1A 0H5

Tél.: (613) 952-6411; Fax.: (613) 991-1261
Courriel: mepa.apme@ic.gc.ca

Abstract

Canada's relatively low business expenditures on R&D (or BERD-intensity) has been attributed to the industrial composition of the Canadian economy, the relatively small size of the domestic market and of Canadian firms and to the relatively high incidence of foreign ownership in the Canadian economy. The main objective of this study is to provide a critical review of firm- and industry-level empirical literature on the impact of industrial structure in general and foreign ownership in particular on business sector R&D performance. The paper argues that while structural explanations for Canada's relatively low BERD-intensity are not without merit, they are not entirely satisfactory. In particular, the evidence on the relationship between firm size and R&D-intensity implies that it is not so much the size of the larger firms that matters for BERD-intensity as the prevalence of firms that are too small to engage in R&D. And while foreign ownership might explain Canada's low BERD-intensity only in a trivial sense, BERD-intensity could be lower than it is now if foreign-owned firms were replaced by a combination of imports and purely domestic firms instead of domestic multi-national firms.

Key words: industrial organization, research and development, foreign ownership, firm size

Résumé

On a attribué le niveau relativement faible de dépenses en R-D des entreprises canadiennes (ou intensité en matière de DRDE) à la composition industrielle de l'économie canadienne, à la taille relativement petite du marché intérieur et des entreprises canadiennes et à l'incidence relativement importante de la propriété étrangère dans l'économie canadienne. Cette étude vise principalement à présenter un examen critique de la documentation empirique, à l'échelle des entreprises et des industries, portant sur l'incidence de la structure industrielle, en général, et de la propriété étrangère, en particulier, sur le rendement en matière de R-D du secteur des entreprises. L'étude fait valoir que, même si les raisons structurelles invoquées pour expliquer la faible intensité en matière de DRDE au Canada ne soient pas sans valeur, elles ne sont pas entièrement satisfaisantes. En particulier, les données relatives au rapport entre la taille d'une entreprise et l'intensité en R-D laissent supposer que ce n'est pas tant la taille des entreprises plus grosses qui importe pour ce qui est de l'intensité en matière de DRDE que la prédominance d'entreprises trop petites pour effectuer de la R-D. Et bien que l'explication de la faible intensité en matière de DRDE au Canada par la propriété étrangère puisse être intéressante, l'intensité en matière de DRDE pourrait être plus faible qu'elle ne l'est maintenant si les entreprises étrangères étaient remplacées par une combinaison d'importations et d'entreprises strictement nationales plutôt que par des entreprises multinationales canadiennes.

Mots clés : organisation industrielle, recherche-développement, propriété étrangère, taille de l'entreprise

Summary

Research and development (R&D) spending is central to the innovative process. Innovation, in turn, is generally regarded as being and having been the driving force behind improvements in living standards. Business R&D spending (as measured by what is known as BERD-intensity) in Canada ranks below a number of other developed countries.

The low ranking of Canada's BERD-intensity relative to other developed countries is taken by some commentators to imply that the Canadian business sector is not as innovative as the business sectors of countries with higher BERD-intensity. There is an ongoing debate as to whether Canada's BERD-intensity ranking is an accurate reflection of the extent of innovative activity within the business enterprise sector of the Canadian economy and if it is, whether this is an unavoidable consequence of the characteristics of the Canadian economy.

Canada's relatively low BERD-intensity has been attributed to the industrial composition of the Canadian economy, the relatively small size of the domestic market and of Canadian firms and to the relatively high incidence of foreign ownership in the Canadian economy. The main objective of this study is to review critically the existing empirical literature, both at the firm level and the industry level, on the impact of industrial structure in general and foreign ownership in particular on business sector R&D performance.

The study cautions that there is more to innovation than BERD-intensity. It finds that while structural explanations for Canada's relatively low BERD-intensity are not without merit, they are not entirely satisfactory. With respect to industrial composition, the low R&D-intensity of a very large Canadian industry, motor vehicle manufacturing, drags Canada's BERD-intensity down. As well, some high-tech industries are relatively smaller in Canada than in comparator countries and some medium-tech manufacturing industries are less R&D-intensive. While some of this may be the inevitable result of the fundamental characteristics of the Canadian economy, some may also be the result of past policy decisions. Regarding firm size, taken at face value, the evidence on the relationship between firm size and R&D-intensity implies that it is not so much the size of the larger firms that matters for BERD-intensity as the prevalence of firms that are too small to engage in R&D.

Foreign ownership might help to explain Canada's low BERD-intensity if it could be assumed that if foreign owned firms did not exist, Canadian-based multinationals would exist in their place. If foreign-owned firms were replaced instead by some combination of imports and purely domestic firms, BERD-intensity would be lower than it is now.

1. Background and Objectives of the Study

Research and development (R&D) spending is central to the innovative process. Innovation, in turn, is generally regarded as being and having been the driving force behind improvements in living standards. Innovative activity may raise living standards yet not be privately profitable. It is for this reason that governments pursue policies that encourage innovative behaviour. National governments have tended to judge the success of their policies in encouraging innovation, in part, by comparing R&D spending in the home economy with R&D spending in other, similarly placed national economies.

There are two commonly used measures of national R&D spending. One is gross domestic expenditures on R&D (GERD). This is the total amount of R&D performed in a country annually. To standardize for the different sizes of national economies. GERD is often expressed as a percentage of gross domestic product (GDP). This is called GERD-intensity. Another commonly used measure of national R&D spending is business enterprise spending on R&D or BERD. Expressed relative to GDP, this is called BERD-intensity. GERD exceeds BERD by the amount of R&D spending in the academic and government sectors of the economy.

Canada's GERD-intensity in 2002 was 1.91 percent putting Canada below Denmark, France, Finland, Germany, Iceland, Japan, Korea, Sweden, Switzerland, United States, among OECD countries and Israel (OECD, 2004, Table 4). Canada's BERD-intensity in 2001 was 0.98 percent putting it below Belgium, Denmark, France, Finland, Germany, Iceland, Japan, Korea, Luxembourg, Sweden, Switzerland, and United States (OECD, 2004, Table 6).

The low ranking of Canada's BERD-intensity relative to other developed countries is taken by some commentators to imply that the Canadian business sector is not as innovative as the business sectors of countries with higher BERD-intensity. There is an ongoing debate as to whether Canada's BERD-intensity ranking is an accurate reflection of the extent of innovative activity within the business enterprise sector of the Canadian economy and if it is, whether this is an unavoidable consequence of the characteristics of the Canadian economy.

Canada's relatively low BERD-intensity has been attributed to the industrial composition of the Canadian economy, the relatively small size of the domestic market and of Canadian firms and to the relatively high incidence of foreign ownership in the Canadian economy. The main objective of this study is to review critically the existing empirical literature, both at the firm level and the industry level, on the impact of industrial structure in general and foreign ownership in particular on business sector R&D performance.

2. The International Ranking of Canada's BERD-intensity and its Possible Significance

In its 2004 study, the Conference Board of Canada (2004) ranked Canada against ten other developed countries according to seventeen indicators of innovative performance. Four categories of indicators were used: (1) Knowledge Performance; (2) Skills Performance; (3) Innovation Environment and; (4) Community Based Innovation. The indicators of knowledge performance used by the Conference Board are: (1) GERD-intensity; (2) BERD-intensity; (3) scientific papers published per capita; (4) "triadic" patents filed;[1] (5) the percentage of university R&D funded by industry and; (6) international technology payments and receipts as a percentage of GDP.

With respect to business R&D spending, the Conference Board reports Canada's BERD: GDP ratio ranked eighth out of eleven. The Board's assessment of this ranking is that while Canada's eighth-place ranking in BERD intensity is "less than impressive," it is nevertheless "a notable achievement" given the structure of the Canadian economy. The structural aspects of the Canadian economy that militate against a higher BERD intensity are, in the Conference Board's view, the larger presence of foreign-controlled firms than other OECD countries, the smaller presence of high-tech firms, the high concentration of business R&D expenditures in a small number of firms, the larger number of small businesses that typically have fewer resources to invest in R&D and the low level of Canadian defence spending which "can serve as a motivator" for business R&D spending.

The Conference Board goes on to emphasize that it is the results of business R&D spending that are more important. It cites some evidence to the effect that Canadian firms derive a smaller fraction of their sales revenue from new products than do firms in some other OECD countries. While the extent to which innovations are commercialized is very difficult to measure in any meaningful way, the Conference Board's concern with commercialization shows a recognition that it is the results of innovative activity that ultimately matter. Moreover, the Conference Board also recognizes that the 17 indicators of innovative performance it uses should serve principally as a basis for further analysis. They are not targets or policy variables. Those focusing on the BERD: GDP ratio as both the main indicator of innovative performance and a target around which policy should be structured should be aware of this.

In his recent commentary on this issue, Harris (2005) concludes that Canada's "weak performance" in business-conducted R&D (BERD-intensity) is "worrisome" in that it is costing Canada in terms of productivity growth and high wage job opportunities (2005, p.16). Professor Harris equates BERD-intensity with

---

[1]Triadic patents are patent applications filed with all three of the U.S., Japanese and European patent offices.

innovation. He makes the now familiar argument that additional investment in innovation yields a higher social (economy-wide) rate of return than other types of investment and that the empirical relationship between BERD-intensity and per capita income growth is a manifestation of this.

Professor Harris' discussion of the case for increasing Canada's BERD-intensity is carefully nuanced. He recognizes first, that a high BERD-intensity is neither necessary nor sufficient for high rates of per capita income growth. There are many factors involved.[2] Second, benefits of domestic R&D spending are not necessarily realized domestically and the Canadian case for free-riding of some sort may be stronger than for other countries. Third, Canada's relatively low BERD-intensity is a consequence, in part, of the structure of the Canadian economy – a structure that is not amenable to rapid change even if a change were desirable. The structural factors mentioned by Professor Harris are the usual suspects: the relative importance of foreign ownership in Canada; the relative importance of less R&D-intensive natural resource industries in Canada and; the relative importance of smaller firms in Canada.

Notwithstanding these reservations, Harris concludes that public policy can and should increase Canada's BERD-intensity. First, he argues that the BERD-intensity of Alberta and British Columbia is too low given the economic characteristics of these provinces and that, as a remedy, the governments of these provinces should offer firm-specific R&D subsidies. Second, he observes that R&D investment is driven, in part, by investment in physical capital and that capital investment in Canada has been inhibited by the relatively high tax rates on capital in Canada. As a remedy, he suggests corporate tax cuts.

Both the Conference Board and Harris studies are careful and both raise interesting questions. Both recognize that Canada's BERD-intensity is a function of its economic structure and that this structure is unique and evolving slowly. The profitability of business R&D spending may be lower in Canada than in other advanced OECD countries. This need not mean that Canada is less innovative than these countries. It does imply, however, that using government incentives to increase business R&D spending is a little like pushing on a string. Given the appropriate economic environment, it may become more profitable over time to engage in innovative activity in Canada but there are no quick fixes. The Conference Board acknowledges this implicitly in its conclusion that Canada needs more large firms in R&D-intensive industries. These cannot be willed into being. Rather, they are a possible long-term product of an open economy, competitive corporate and personal taxation, "smart' regulation and strong supporting institutions. Professor Harris sees quicker possible fixes in the form of lower capital taxes (which would be beneficial regardless of their effect on

[2] An excellent discussion of the many factors have or may have influenced the rate of productivity growth and the rate of per capita income growth in Canada and in other OECD countries can be found in Pilat (2005).

R&D spending) and provincial R&D subsidies (which are questionable for a variety of reasons).

There may be reason for policy makers to be concerned about Canada's relatively low BERD-intensity. Just how concerned is a question that this study attempts to address. While R&D spending is an important measure of the resources devoted to innovative activity, it is not a measure of innovation itself. Whether it is as good a measure of the amount of innovation occurring in Canada as it is in other countries is an open question.[3] Even if BERD-intensity is a reasonable indicator of innovative activity, it may make a poor policy lever.

The BERD:GDP ratio is less important for its own sake than for what it implies about the costs and benefits of profit-oriented innovation in Canada. Business R&D spending is a response to an economic climate that is conducive to innovation. The question then becomes what it is about Canada that makes innovation less attractive than in other advanced economies? There is the usual list of suspects: foreign ownership, firm size, industrial composition, market size, population density, proximity to markets. Given the acknowledged importance of economic structure in determining the economy-wide BERD-intensity, it is instructive to explore in greater detail what the nature of the role played by economic structure in determining BERD-intensity differences between Canada and other countries. To what extent is Canada's BERD-intensity an inevitable product of its resource endowment, geography, demography and history? To what extent is it amenable to public policy?

3. The Effect of Industrial Composition on Canada's BERD Intensity

A recent paper by ab Iorwerth (2005) investigates the role of industrial structure in explaining BERD-intensity differences between Canada and other advanced OECD countries. BERD-intensity in Canada could be lower than in comparator countries either because individual Canadian industries are less R&D-intensive than their counterparts in comparator countries (intensity effect) or because R&D-intensive industries account for a smaller fraction of GDP in Canada than they do in comparator countries (industry mix effect) or both. In his study, ab Iorwerth isolates the respective roles of intensity effects and industry mix effects in explaining the .88 percentage point difference between the U.S. and Canadian BERD-intensities.[4]

---

[3] For example, a recent study by Sharpe and Guillbaud (2005) has found that while they do have a relatively low R&D-intensity and they are relatively prominent in Canada, the natural resource industries turn out to be comparable internationally when their innovative activities are examined more closely.

[4] 1999 BERD was 1.94 percent of GDP in the U.S. and 1.06 percent of GDP in Canada (ab Iorwerth, 2005, Tables 1 and 2)

The first finding of the ab Iorwerth study is that the relative prominence of the natural resource sectors in the Canadian economy explains little if any of the difference in the respective BERD-intensities of the two countries (2005, pp.23-5). The entire explanation is found in the service and manufacturing sectors rather than the primary sectors of the Canadian economy.

The author's second finding is that of the 0.88 percentage point difference between U.S. and Canadian BERD-intensity, 0.60 percentage points is due to the lower research intensity of some Canadian industries relative to their U.S. counterparts. It is important to note in this regard that Canadian industries are not uniformly less R&D-intensive than their U.S. counterparts. As Table 1 shows, several Canadian industries, including some high-tech industries, are more R&D-intensive than their U.S. counterparts. Among the Canadian industries that are less R&D-intensive than their U.S. counterparts, two, the services sector and motor vehicle manufacturing, stand out.

The author suggests that the shortfall in services R&D-intensity in Canada is caused by the wholesale and retail trade industry but declines to speculate about what this could mean. One possibility would be the relative importance of large electronic retailers and wholesalers in the U.S. Another possibility is that international outsourcing may have led to the reclassification of some R&D-intensive U.S. manufacturing firms as service sector firms.[5] This matter is worthy of further investigation.

With respect to motor vehicle manufacturing, R&D operations of automobile manufacturers have historically been located in the U.S. This might have been changed at the time the Canada - U.S. Auto Pact was negotiated but Canadian negotiators were more concerned with production employment and content guarantees at the time.[6] As Japanese and other manufacturers have decentralized their R&D activities, they too have tended to locate in the U.S.[7]

---

[5] I am indebted to Surendra Gera on this point.

[6] In his paper, "Power Steering the Auto Industry" Keith Acheson (1989) takes us back to the 1961 Bladen Report which lamented the lack of R&D done in the automobile industry in Canada and recommended the exercise of moral suasion on the parents. Acheson notes that when the Auto Pact was negotiated, Canada could have bargained for R&D jobs or content but chose instead to bargain strictly for manufacturing jobs and content. Acheson also notes that the Reisman report in 1978 recommended that R&D be given double weight when measuring Canadian content for purposes of the Auto Pact. Of course, by then the manufacturers had significantly exceeded their Canadian content requirements and double weighting R&D would not have mattered.

[7] Toyota, Nissan and Hyundai along with many foreign-owned auto parts suppliers have major R&D facilities in Michigan. Automotive and related R&D is estimated to employ 60,000 at 200 companies in Michigan with R&D spending in

Of the 0.88 percentage point difference between U.S. and Canadian BERD-intensity, 0.28 percentage points is due to differences in industry mix. In essence, some of the most R&D intensive industries, in particular the Radio, TV, Communications Equipment industry, the Office, Accounting, Computing Equipment industry and the Pharmaceuticals industry account for a smaller share of GDP in Canada than they do in the U.S. While these industries are more R&D-intensive than their U.S. counterparts (indeed, more R&D-intensive than their counterparts in many other OECD countries), they also account for a smaller share of the economy than they do in the U.S. and this negative industry mix effect partially offsets the positive R&D-intensity effect.

In the case of the Services sector there is both a negative R&D intensity effect and a negative industry mix effect. That is, the Services sector in Canada is both less R&D intensive than its U.S. counterpart and it also accounts for a smaller portion of GDP than its U.S. counterpart.

Table 1
Effect of Differences in Industry R&D-Intensity on the Difference Between BERD-Intensity in Canada and the U.S.

Negative intensity effects	0.85pp	Positive Intensity Effects	0.25pp
Motor vehicles	-0.30	Radio, TV, communications equipment	0.11
Services	-0.24	Office, accounting, computing equipment	0.07
Other transportation equipment	-0.08	Pharmaceuticals	0.03
Refined petroleum, plastics, chemicals	-0.08	Utilities	0.02
Machinery & equipment n.e.c.	-0.04		

Source, ab Iorwerth, Table 8

A third finding of the ab Iorwerth study is that international rankings of R&D intensity are sensitive, at least in Canada's case, to the industries that are included in the ranking. As stated above, Canada ranks eleventh among OECD countries in BERD-intensity. When only the five most R&D-intensive industries

---

2002 amounting to $10.3 billion (U.S.). Michigan accounts for 80 percent of automotive R&D in the U.S with California ranking a distant second. See the Lansing State Journal (October 6, 2005) at http://www.lsj.com/apps/pbcs.dll/article?AID=/20051006/NEWS03/510060328/1004/ARCHIVES

(internationally) are considered, Canada's average R&D-intensity ranking is 6.6 (the highest possible average rank is one and the lowest, fifteen). Canada ranks fifth in its average ranking. When the Motor Vehicles industry is excluded, Canada's average rank improves to 4.8 and this is the third highest average ranking in the fifteen country group.

In sum, with the exception of the Motor Vehicles industry, Canada ranks well internationally in the most R&D-intensive industries. Canada's relatively weaker showing in terms of the BERD:GDP ratio is a consequence of the relatively small size of these industries, the low R&D-intensity of the Motor Vehicles industry in Canada and the relatively low R&D-intensity of a number of "medium-tech" manufacturing industries in Canada.

Insofar as the implications of these findings are concerned, the first is that R&D intensities sometimes do not tell us very much. The fact that R&D in motor vehicle manufacturing is located disproportionately in the U.S. does not appear to have resulted in a Canadian industry that is less productive or less technologically advanced than its U.S. counterpart.[8] The fact that the Canadian pharmaceuticals industry has a higher R&D: value added ratio than its U.S. counterpart would not be taken by many to imply that it is more innovative than its U.S. counterpart. Much of the R&D activity in the Canadian pharmaceuticals industry is a consequence of a political bargain under which manufacturers of patented pharmaceuticals agreed to conduct a pro rata share (relative to sales) of their R&D in Canada in return for the repeal by Canada of provisions of the Patent Act allowing for compulsory licensing of patented drugs. When R&D intensity is measured relative to value added as the ab Iorwerth study does, the Canadian industry may appear more R&D-intensive than its U.S. and other foreign counterparts but this may say as much about the absence of other value adding activity in Canada as it does about research orientation.

A second implication of the ab Iorwerth findings is that industry differences matter. Some Canadian industries are as R&D-intensive as any internationally. Similarly, as the work of John Baldwin and his colleagues (reviewed below) shows, some Canadian multinationals are as innovative as any. This may militate against general cultural, regulatory, tax, educational and financial market explanations for Canada's relatively low BERD intensity but it may not. Some Canadian firms and industries may have world class standing of some sort, but the ab Iorwerth findings do nothing to contradict the observation of the Conference Board and Harris studies that the number of firms that have done so is relatively small.

---

[8] "2002 car assembly plant rankings by vehicle segment – hours per vehicle (HPV) including launch," Detroit News Special Report, February 22, 2004. http://www.detnews.com/specialreports/2004/plants/carplants.htm

4. Review of Empirical Studies of the Effects of Firm Size and Foreign Ownership on R&D-Intensity

It is generally argued that part of the explanation of Canada's relatively low BERD-intensity lies in the relatively small size of Canadian firms and in the relatively greater incidence of foreign ownership in Canada. The argument is that R&D-intensity increases with firm size and that the foreign-owned firms are less R&D-intensive than their domestically owned counterparts. The first question to examine is whether this argument has a sound factual basis. The second question is, to the extent that it is soundly based, what its implications are. This is especially important in regard to the relationship between ownership and R&D-intensity.

4.1 Canadian studies

Holbrook and Squires (1996) estimate the relationship between R&D spending and sales (and between R&D employment and total employment) for a sample of R&D performing firms in various Canadian manufacturing and service industries during the period 1981-1989. They posit a relationship between R&D and sales that is linear in logarithms. They estimate their model on an industry by industry basis and allow the slope and (logarithmic) intercept coefficients to differ between foreign and domestically controlled firms. The slope coefficients in this model are direct estimates of the elasticity of R&D with respect to firm size. The authors find that the elasticity of R&D spending (or R&D employment) with respect to firm size is less than one in almost all industries. This implies that R&D-intensity declines as firm size increases and is not consistent with results reported for other countries (see below). The authors also find that the elasticity of R&D spending (or R&D employment) with respect to firm size is higher for foreign controlled firms than for Canadian-controlled firms in most industries. The authors interpret this as implying that their results offer "... little support for the hypothesis that foreign-owned performers are less willing to perform R&D in Canada than their Canadian-owned counterparts." (p.371)

The conclusion reached by Holbrook and Squires is more sweeping than the results they report will support. The authors do not report estimates of the intercept coefficients of their models. Figures 1 and 3 in their paper imply that these intercepts are greater for Canadian-controlled firms than for foreign-controlled firms. This implies, in turn, that there is a range of smaller firm sizes over which Canadian-controlled firms are more R&D-intensive than their foreign-controlled counterparts. The threshold firm size at which foreign controlled firms become more R&D intensive than their Canadian-controlled counterparts depends on values of the slope and intercept coefficients and this differs from industry to industry. The distribution of foreign controlled firms above and below the threshold depends on the industry.

The Holbrook and Squires analysis has its defects, some of which are potentially quite serious. The sample includes no non-R&D-performing firms. The sample is a pooled time series-cross-section but the econometric specification the authors use does not take its time series component into account. That is, there is no recognition of the possibility that the cross-sectional relationship between R&D and firm size may shift over time. Taken at face value, however, these results have the important implications that R&D spending depends on firm size and that this relationship differs both from industry to industry and between foreign and domestically controlled firms. Whether a foreign-controlled firm is more R&D-intensive than a domestically controlled firm depends on the industry and the size of the firms involved.

Tang and Rao (2001) examine data on 28 Canadian controlled and 30 foreign-controlled, publicly-traded, R&D-performing manufacturing firms over the period 1985-1994. The authors' statistical test involves a regression of R&D-intensity on a foreign control dummy, two firm size dummies, a high-tech industry sector dummy, an export dummy and a time dummy. The dummy variable for high-tech industries classifies the following industries as high-tech: chemicals; petroleum and coal products; electrical and electronic products and; industrial machinery. These authors find that, holding the factors listed above constant, the foreign-controlled firms in their sample had a lower R&D intensity than the Canadian-controlled firms. The authors interpret their results as follows:

> First, foreign-controlled firms spend significantly less on R&D than Canadian-controlled firms after controlling for other factors. Second, as expected, the R&D propensity of high tech and export-oriented firms is significantly higher than that of low-tech and non-exporting firms. Third, R&D propensity and firm size are significantly negatively related. (2001, p.8)

Obvious problems with this experiment are that the sample is restricted to listed companies and includes no non-R&D performing firms. The experimental design fails to allow for inter-industry differences in R&D opportunities and constrains the marginal effects of all the explanatory variables in the model (except the time trend) to be the same for foreign and domestic firms. In particular, the size effect is not allowed to differ between foreign and domestically controlled firms thus ruling out the possibility that foreign-controlled firms might be more R&D-intensive over some size ranges. The export dummy variable also complicates interpretation of both the size-R&D relationship and the ownership-R&D relationship. The authors find that exporting firms are more R&D-intensive. But large firms may be more likely to export (indeed, large firms are exporters almost by definition) so the possibility that large firms are equally R&D-intensive cannot be ruled out. Similar reasoning holds for the possible relationship between ownership and exporting behaviour.

Baldwin and Hanel (2003) analyze the determinants of the probability that a firm in Canada engages in ongoing R&D. They hold firm size and sector constant. Industry sectors are defined as follows: (a) Core sector – Machinery, Electrical and Electronic Products, Refined Petroleum and Coal, Chemicals & Pharmaceuticals; (b) Secondary sector – Rubber, Plastic, Primary Metal, Fabricated Metal, Transportation Equipment, Non-metallic Mineral Products; (c) Other – Food, Beverages & Tobacco, Leather, Clothing, Primary Textile, Textile Products, Wood, Furniture & Fixtures, Paper, Printing & Publishing and Other. The authors distinguish among three types of firms, foreign-owned, domestically-owned with no foreign sales or plants and domestically-owned with foreign sales or plants. They find that the probability that a firm engages in ongoing R&D increases with firm size and is greater in the core sector. There is no difference between foreign-owned firms and either category of domestically-owned firms in the probability of engaging in ongoing R&D. (Table 10.5) They draw the conclusion that foreign owned firms are at least as likely to conduct R&D in Canada as are domestically controlled firms even after their larger size and industry location are both taken into account. (p.282)

In their analysis of the effect of firm size on the probability of engaging in ongoing R&D. Baldwin and Hanel make use of four employment size classes: 1 – 20 employees; 21 – 100 employees; 101 – 500 employees and; over 500 employees. The authors find that the probability that a firm engages in ongoing R&D ranges from 22 percent in the smallest size class to 60 percent in the largest size class (2003, Table 10.6). Thus, large firms have a higher probability of engaging in ongoing R&D.

The Baldwin-Hanel results do not speak directly either to the effect of foreign ownership on R&D-intensity or to the effect of firm size on R&D-intensity. Moreover, these results could be confounded by inter-industry differences in R&D opportunities within the core group of industries. That is, foreign-owned firms could be concentrated in one of the more or less R&D-intensive industries within the core group.

It is an obvious criticism that these authors should standardize for industry differences within both the core and the secondary sectors. The problem is that samples get a little thin when attempts are made to hold size, industry and ownership constant. Indeed, the question arises as to whether a statistically meaningful comparison between foreign and domestically owned firms of the same size and in the same line of business is even possible in Canada. Foreign and purely domestic firms are likely to differ in many dimensions in addition to R&D spending.

In a subsequent paper, Baldwin and Gu (2004) examine the respective effects of firm size and ownership on the probability of engaging in ongoing R&D, holding two digit industry effects constant. While two digit industries still represent fairly broad aggregations, they are much more refined than the core/secondary/ other

industry categorization employed by Baldwin and Hanel (2003). Baldwin and Gu find that holding two digit industry effects and firm size constant, Canadian-controlled multinationals are more likely to engage in ongoing R&D in Canada than foreign-controlled multinationals and foreign controlled multinationals are more likely to engage in ongoing R&D in Canada than purely domestic Canadian firms.[9] They also find that the probability of engaging in ongoing R&D increases with firm size.[10]

In interpreting the studies discussed above, it is important to recognize that they either have no time series element or they do not make use of the time series observations they have. In the simplest terms, to find that foreign-controlled firms are less R&D-intensive than domestically controlled firms does not imply much about how quickly R&D-intensity would change if the nationality of control were to change. Similarly, these studies do not tell us how quickly R&D-intensity changes as sales or employment change.

4.2 Studies from other countries

There is considerable international evidence on the determinants of R&D spending in general and on the relationship between firm size and R&D spending in particular. There are fewer studies on the relationship between the nationality of ownership and R&D spending by firms although the number of such studies is beginning to grow.

The evidence on the relationship between firm size and R&D spending has been summarized in a number of papers. Link, Seaks and Woodbery (1988) interpreted the extant literature as implying that the elasticity of R&D spending with respect to firm size is constant and close to unity across firm sizes within industries. Their own empirical work supports this conclusion.

The evidence on the relationship between firm size and R&D spending has also been surveyed by Cohen and Klepper (1996) who characterized the empirical literature as implying that, within industries, the probability that a firm engages in R&D increases with firm size and that, among R&D performers, the elasticity of R&D spending with respect to firm size generally does not differ statistically from one. These two findings imply that, above what the authors call a modest

---

[9] The difference between the probability that Canadian-controlled multinationals engage in ongoing R&D in Canada and the probability that foreign-controlled multinationals engage in ongoing R&D in Canada is statistically significant only at the 10 percent level. The authors do not directly test the null hypothesis that the respective probabilities that foreign multinationals and purely domestic firms conduct ongoing R&D in Canada do not differ (Baldwin and Gu, 2004, Table 4).

[10] Baldwin and Gu (2004) differ from Baldwin and Hanel (2003) in that they make use of a single size variable.

threshold firm size, larger average firm size does not result in increased aggregate R&D spending. The authors' own empirical results imply that the size-R&D relationship is line of business-specific. Adding sales from another line of business does not result in a commensurate increase in R&D activity.

Becker and Pain (2003) survey the literature on the determinants of R&D spending by firms. They cite as determinants cash flow, size (with the effects of the two being difficult to disentangle), the incidence of unionization, the intensity of competition in the relevant product market, government subsidies, tax credits and R&D spending and the R&D spending of nearby firms. While these authors do not cite the nationality of ownership as a potential determining factor, they do note that the possibility that R&D spending by foreign controlled firms may either encourage or discourage R&D spending by domestic firms has been investigated.

In their own empirical work which utilizes industry level data for Britain, Becker and Pain find that they can not reject the hypothesis that the elasticity of industry R&D spending with respect to industry output is one and that industry R&D spending is higher in industries in which the share of R&D spending accounted for by foreign controlled firms is higher.[11]

Griffith, Redding and Simpson (2004) have compared the respective R&D intensities of foreign multinational, British multinational and domestic firms in Britain. They make their comparison on an industry by industry basis but do not take size effects into account. They find that the British subsidiaries of foreign multinationals tend to be less R&D-intensive than British multinationals but more R&D-intensive than domestic British firms.

As part of a larger study, Ebersberger and Loof (2005) use data from the Nordic countries to examine the relationship between firm characteristics including size and ownership on one hand and various measures of innovative performance including the probability of engaging in R&D, R&D-intensity and productivity growth on the other. It is difficult to draw general conclusions from this study because the results differ both across host countries and across the home countries of the firms involved. The authors interpret their results as follows: (1) foreign-owned firms do not differ from host country firms in their propensity to engage in R&D; (2) the R&D-intensity of domestic multinationals tends to exceed that of both foreign-owned firms and purely domestic firms; (3) R&D-intensity declines as firm size increases and; (4) foreign-owned firms do not differ from domestic multinationals with respect to various measures of innovative output including productivity growth.

---

[11] This is primarily a result of the imprecision of their estimate of the output elasticity of R&D spending. Becker and Pain would not be able to reject the hypothesis that this elasticity is 0.5 either.

Ebersberger and Loof find it paradoxical that domestic multinationals use more innovative inputs than foreign-owned firms but get the same innovative output. They posit that this is because foreign-owned firms can rely in part on knowledge transferred from their parent company, a suggestion that will be familiar to Canadian students of foreign ownership. This same phenomenon poses a hazard for comparisons of the innovative productivity of foreign firms with domestic multinationals. If R&D tends to be centralized at home and knowledge is transferred to affiliates, the R&D productivity of the parent is always going to appear lower than that of the affiliate unless all knowledge transfers are fully valued.

While comparisons of the two studies are somewhat hazardous, two important differences between the findings of Ebersberger and Loof for the Nordic countries and those of Baldwin and Hanel (2003) for Canada are: (1) foreign-owned firms do not differ from purely domestic firms in a number of respects in the Nordic countries while they clearly do in Canada and; (2) domestic multinationals are much more embedded than foreign-owned firms in the host country innovation system in the Nordic countries while in Canada the two groups are equally well embedded in the innovation system. [12]

Table 2
R&D-Intensity in British Firms

	British Domestic	British Multinational	Foreign Multinational
	Intramural R&D as a % of Value Added		
Pharmaceuticals and Chemicals	19	42	23
Mechanical engineering and electrical machinery	3	13	11
Transport equipment and aerospace	6	29	14
Other manufacturing	2	3	2
Services	1	2	1

Griffith, Redding and Simpson, Table 5

[12] For reasons that would appear to have a limited basis in economics, Ebersberger and Loof break foreign-owned firms down into four classes: Nordic, Anglo Saxon, continental and other. Moreover, they employ industry groupings such as "high-tech manufacturing" etc., which leaves open the possibility of inter-industry variation within these groupings.

4.3 Interpretation of evidence on the relationship between firm size and R&D-intensity

The Canadian studies reviewed here imply that among R&D performers, R&D-intensity decreases as firm size increases but that the probability of being an R&D performer increases with firm size. Taken at face value, these results imply that R&D-intensity could increase over smaller size ranges as firms become R&D performers and decrease over larger size ranges. Larger average firm size would not necessarily imply higher industry R&D-intensity.

The findings of international studies of the relationship between firm size and R&D spending also imply that the probability of being an R&D performer increases with firm size. A number of these studies further imply that the elasticity of R&D spending with respect to firm size is one although the elasticity estimate is not precise. The international evidence implies that for a given firm, R&D-intensity increases (from zero) as the firm passes the minimum size threshold and remains constant thereafter. Viewed on an industry basis, these results imply that industry R&D-intensity depends on the proportion of industry sales (if that is the size variable) accounted for by firms over the minimum size threshold. Increases in average firm size which do not change the proportion of industry sales accounted for by firms over the minimum size threshold do not change industry R&D-intensity. On this evidence, replacing two firms that are already above the minimum size threshold with one firm that is twice as large does not increase industry R&D-intensity.

Keeping in mind the caveats that specifications of the relationship between R&D spending are highly simplified and that estimates of the elasticity of R&D spending with respect to firm size are imprecise, the implication of both the Canadian and the international studies is that if Canada's relatively low BERD-intensity is due, in part, to smaller average firm sizes in Canada, it must be the case either that firms below the size threshold at which a firm becomes an R&D performer account for a greater portion of sales in Canada or that there is a higher minimum size threshold in Canada.

While it is important not to read too much into estimates of the firm size-R&D spending relationship, those concerned strictly with BERD-intensity would be better advised to focus their attention on the lower end rather than on the upper end of the firm size distribution. The size threshold at which a firm becomes an R&D performer likely varies from industry to industry and depends at least in some circumstances on how size is measured. There are instances in which firms have R&D but no sales and groups of firms with R&D: Sales ratios in excess of one.

4.4 Interpretation of evidence on the relationship between the nationality of ownership and R&D-intensity

Existing econometric studies of the relationship between foreign control and R&D intensity are something less than definitive. They are dated, handicapped by data limitations and, in some cases, subject to potentially crippling design flaws. Foreign-controlled firms may appear more R&D-intensive because they are massed in R&D-intensive industries or less R&D-intensive because they are relatively large. It is certainly possible to do better but a comparison of truly matched pairs is probably not in the cards and, in any event, for reasons given below, the question is not a very interesting one.

Baldwin and Gu (2004) have found that, given size and industry effects, foreign owned firms are more likely to engage in R&D spending in Canada than are purely domestic firms but less likely to do so than are Canadian-controlled multinationals. While this does not speak directly to the intensity question (although if the size elasticity were one for all performers, domestic multinationals of a given size would be more R&D-intensive than their foreign counterparts), it is consistent with the evidence that multinationals spend a disproportionate fraction of their R&D budgets in their home countries.

Suppose that foreign-owned firms are less R&D-intensive in Canada than a Canadian controlled multinational with the same domestic sales and in the same industry. What are we to make of this? Depending on the counterfactual, it could be a reason that the BERD:GDP ratio is lower in Canada than in some other OECD countries. The argument in this regard is not compelling. Leave aside the question of whether the contribution of foreign owned firms to domestic innovation can be assessed in terms of R&D-intensity. The argument that Canada's low BERD can be "explained" in part by foreign ownership assumes that existing foreign firms have displaced domestically controlled multinationals. That is, if there were no IBM Canada there would be a "BeaverComp" Canadian controlled multinational computer company in its place and it would spend much more on R&D in Canada. Perhaps, but it could also be that if IBM Canada did not exist it would have been replaced by some mixture of imports, purely domestic firms (which, on the evidence, are less R&D-intensive than foreign-owned firms) or possibly a Canadian-based multinational. Even in this case the Canadian-based multinational would be facing strong centrifugal forces on it R&D location decisions (see Section 5 below). Whether or not Canada's BERD-intensity would be higher if there were less foreign ownership in Canada would appear to be moot at best.

Even if foreign ownership were to "explain" Canada's relatively low BERD-intensity, this would not itself have any policy implications. Domestic firms may grow to international standing given an open economy and a hospitable tax and regulatory climate. Attempts to discourage foreign takeovers or enforce so-called performance guarantees have been failures in the past as have attempts at

repatriating ownership. It is now recognized that forbidding take-overs by the highest bidder simply reduces the incentive for domestic entrepreneurs to start new businesses and build them up. Moreover, the exigencies of risk-spreading are such that, with an efficient global capital market, it is highly unlikely that share ownership in a growing, innovative firm would be concentrated in one country in any event.

5. Review of Empirical Studies of the Effect of Foreign Ownership on Alternate Measures of Innovative Activity

While R&D spending is central to the innovative process, it is by no means essential in all cases. Nor does spending on R&D guarantee that innovation occurs and diffuses throughout the economy. For these reasons it is unfortunate that policy discussions often centre on R&D spending. A broader examination of the innovative process is especially important in the case of multinational enterprise because this organizational form exists in part to transfer intangible assets including knowledge to and, more recently, among host countries. In essence, the role played by foreign owned firms in host country innovation systems might not be accurately reflected by their local R&D intensity.

There are many different measures of either the resources devoted to innovative activity or the results of innovative activity. Innovation surveys attempt to measure the extent of new product or process innovation directly. There is also survey evidence on the adoption of advanced technologies. The results of the introduction and diffusion of innovations should ultimately be manifest in higher productivity levels and rates of productivity growth.

Research conducted in a variety of OECD countries and summarized by the OECD (2005, pp.172-7) concludes that foreign owned firms are typically more productive and have higher productivity growth rates than purely domestic firms. Foreign owned firms occasionally out-perform domestic multinationals in these dimensions. In a Canadian context, Baldwin and Gu (2004, Table 2) find that, given firm size and holding two digit industry effects constant, labour productivity is the same in both Canadian and foreign controlled multinationals and both are higher than in purely domestic firms. In the case of labour productivity growth, Baldwin and Gu (2004, Table 6) show that it has been much faster in foreign-owned plants than in domestically owned plants. In making this comparison the authors do not hold industry effects constant and do not distinguish between domestic multinationals and purely domestic firms.

Baldwin and Hanel (2003) investigate the effect of foreign ownership on the probability of introducing a product or process innovation. The authors find that, within the core (R&D-intensive) industry grouping, the percentage of foreign-owned firms innovating may be higher or lower than the percentage of domestic

multinationals innovating depending on the size class of firm. In the largest employment size class, the respective percentages innovating are essentially the same. In the middle employment size class (100 – 500 employees), a higher percentage of domestic multinationals innovates. In the smallest size class, the percentage of foreign-owned firms innovating in Canada exceeds both the percentage of domestic multinationals and the percentage of purely domestic firms innovating (2003, Table 10.15).

Baldwin and Gu (2004) analyze the effect of foreign ownership on the probability of innovating and on the probability of using advanced technologies. They employ multivariate regression analysis and hold two digit industry effects constant. They find that the probability of introducing a product or process innovation in Canada is greater for domestic multinationals than for foreign owned firms and is greater for foreign-owned firms than for purely domestic firms.[13] The probability of innovating also increases with firm size (2004, Table 4). The probability of using advanced technologies increases with firm size and is higher for both foreign and domestic multinationals than it is for purely domestic firms (2004, Table 5). The authors take their results to imply that if there is an innovation gap between Canadian firms and firms in other OECD countries, it "... reflects the poor innovation performance of domestically oriented firms in Canada." (2004, p.16)

Foreign owned firms may also confer spillover benefits on host economies. These spillover benefits may take the form of knowledge or knowhow that host country firms are able to acquire from foreign owned firms and for which the foreign owned firms involved are not compensated. There is some evidence that these positive spillovers do, in fact, occur. For example, a study by Keller and Yeaple (2003) estimated that 14 percent of U.S. productivity growth between 1987 and 1996 was attributable to technology spillovers emanating from foreign affiliates in the U.S. In their review of the evidence in this regard, however, Head and Reiss (2004) concluded that the evidence regarding spillover benefits is "mixed." (p.24)

In Canada, Baldwin and Gu (2004, Table 7) find that given industry and plant characteristics, the growth in labour productivity in Canadian-owned manufacturing plants was higher the greater is the share of industry shipments or employment accounted for by foreign-owned firms. While this seems to imply a spillover effect, this model does not control completely for industry fixed effects. It may also be the case that Canadian plants in industries characterized by a

[13] Baldwin and Gu (2004, Table 4) do not directly test the null hypothesis that foreign-owned firms are more likely to innovate than purely domestic firms. Their results imply that foreign owned firms have a higher probability of innovating but the statistical significance of this result cannot be determined on the basis of the results they report.

greater incidence of foreign ownership are more likely to be owned by Canadian multinationals and experience faster productivity growth for that reason.

The burden of the evidence regarding the role played by foreign owned firms in is that they raise the productivity and ultimately the living standards of host economies. Their presence could be regarded as "explaining" weaker innovative performance in host economies only in the context of the Nirvana counterfactual hypothesis that they could be replaced by over-achieving domestically-based multinationals.

Regardless of whether foreign ownership can be viewed as explaining Canada's relatively low BERD-intensity, those concerned with raising it, if only for its own sake, may ask whether the R&D-intensity of affiliates is likely to increase relative to parents in what countries and under what circumstances. This question is addressed in the next section.

6. Review of Empirical Studies of the International Allocation of R&D by Multinational Enterprises

It is generally accepted that the R&D activities of multinational enterprises are gradually but steadily being decentralized internationally. There are several indicators of the extent of decentralization. One indicator is the percentage of business R&D spending accounted for by foreign affiliates. The OECD (2005, p.170) notes that in most advanced countries the portion of business R&D accounted for by affiliates has increased over time. Data presented by Moris (2004) show that the percentage of U.S. industrial R&D accounted for by affiliates of foreign companies increased 13 percent in 1994 to nearly 15 percent in 2001. Of course, the ratio of domestic to foreign affiliate business R&D spending in any one country could change for a variety of reasons unrelated to decentralization. In the case of the U.S., for example, it could be the case that foreign affiliates are growing faster than domestic firms. Indeed, Moris also shows that foreign affiliates in the U.S. did not become more R&D-intensive over the 1994-2001 period implying that R&D was not decentralized to the U.S. at a greater rate than the production, marketing and other activities of foreign firms.

Another indicator of decentralization is the ratio of affiliate R&D to parent R&D. The surveys of U.S. foreign direct investment carried out by the U.S. Department of Commerce show that affiliate R&D has increased relative to parent R&D over time. As Table 3 indicates, majority-owned affiliate R&D as a percentage of U.S. parent R&D has grown from 6.8 percent in 1982 to 15.9 percent in 2003. The table also shows that R&D in Canadian majority-owned affiliates also increased relative to U.S. parents although it has decreased as a percentage of all affiliate R&D. Again, this is consistent differences in the respective growth rates of affiliates and parents. Acquisitions, divestitures and exchange rate variation may also affect this comparison. A better indicator of decentralization might be to

compare the respective R&D-intensities of parents and affiliates on an industry basis over time.

Table 3
Majority Affiliate R&D as a Percentage of U.S. Parent R&D 1982 - 2003

	1982	1989	1994	1999	2003
	Percent				
All Majority affiliates / All U.S. parents	6.8	9.6	13.0	14.4	15.9
Canadian majority affiliates / All U.S. parents	0.9	1.2	0.9	1.3	1.8
Canadian majority affiliates / All majority affiliates	13.1	12.3	7.0	9.3	11.0

Source: Mataloni (2005) Tables 10.2 and 12.2; Moris (2004), Table 6 ; U.S Department of Commerce, Bureau of Economic Analysis, U.S Direct Investment Abroad, 1989 Benchmark Survey, Tables II.R 1 and III.I 1; U.S Department of Commerce, Bureau of Economic Analysis, U.S Direct Investment Abroad, 1982 Benchmark Survey, Tables II.Q 1 and III.H 5;

6.1 Categorization of foreign R&D operations of multinational enterprises

A survey of 151 foreign R&D units operated by 20 Swedish multinationals characterized 32 as market oriented, 21 as production support units, 13 as research units, 29 as politically motivated and 56 as multiple motives (Hakanson and Nobel, 1993b pp.400-401). The authors noted that most of the politically motivated R&D units were recently acquired at the time of the survey and might ultimately be closed. They also noted that market oriented R&D units could be either oriented strictly to the local market or be mandated to cover a set of foreign markets with common characteristics.

A survey of 1021 R&D locations by Von Zedwitz and Gassman (2002) yielded the following classification of R&D location strategies: (1) purely domestic (10/81); (2) market driven (centralized research and decentralized development) (42/81); (3) technology driven (centralized development and decentralized research) (7/81) and; (4) globalized (decentralized research and development) (19/81). Three companies could not be classified (p.576). The authors also note that decentralization is increasing and that most international R&D operations are in a state of evolution with either development or research being decentralized or one following the other (p.580).

6.2 Drivers of international R&D decentralization

The traditional view of the location of R&D activities by multinationals is that these activities are conducted at home and are decentralized only to the extent necessary to support foreign production or large, idiosyncratic foreign customers. More recently, it has been recognized that R&D can also be decentralized in the

pursuit of technological spillovers or to access lower cost pools of scientific and technological talent. Cantwell and Piscitello (2004) summarize this newer theory as follows:

> ... the closer international corporate integration that has occurred in the leading MNCs since the 1960s, aims to establish geographically dispersed networks for the purpose of the transfer of technology, skills and assets across national borders between the parent company and its affiliates. The sustainable competitive advantage built on this transfer lies in the two-way interaction between parent and subsidiaries. Local laboratories play a new role within the whole corporate structure by sourcing new knowledge from the local environment rather than carrying out merely demand-oriented activities. Starting from the idea that increasing returns are essentially a regional and local phenomenon arising from regional economic agglomeration and specialisation, different approaches emphasizing the role of local spatial areas for the purpose of global competitiveness, have flourished in recent economy theory. Specifically, in analysing the internationalisation strategy of MNCs, it emerges clearly that multinationals target local spatial areas where they can enjoy externalities and spillovers (2004, pp.4-5)

There have been a number of empirical studies of the determinants of R&D decentralization. In their early study of the motives for R&D decentralization, Hakanson and Nobel (1993a) found that market proximity and adaptation of manufacturing processes to local market conditions were the most prominent motives for decentralization with monitoring the development and technology of competitors abroad being of secondary importance (p.383). Political factors were also a common secondary consideration especially in the case of acquired facilities (p.384).

Kumar (2001) attempts to determine the relative importance of these motives. He finds that foreign R&D by U.S. multinationals is determined by the size of the host country market, and the technological sophistication of the host country as well as industry effects.

LeBas and Sierra (2002) find that, based on European patents granted to multinational enterprises over the period, the two most prominent decentralization strategies are home R&D augmentation and home R&D exploitation. In the simplest terms, European patent applications by individual multinationals tend to be concentrated in technological fields in which they are relatively strong (in terms of revealed comparative advantage) in their home country. If the multinational involved is also relatively strong in the same technological field in the host country (the country in which the multinational makes the invention) then it is deemed to be pursuing a home country R&D augmentation strategy. If the multinational is relatively weak in the host country in the technological field involved it is deemed to be pursuing a home country

R&D exploitation strategy. By this measure, pure knowledge seeking decentralization (inventions occurring in fields in which the multinational is relatively strong in the host country but relatively weak in the home country) is not common.

Le Bas and Sierra also find that the degree to which patents granted arises from inventions made outside the home country varies across technological fields, and according to the nationality of the multinationals involved. Japanese multinationals are the least likely to decentralize while Swiss and Dutch multinationals are the most likely to decentralize. The United States is by far the most important host country source of inventions with Japan and Germany being second and third. The portion of patents arising from inventions made in host countries has also risen over time.

Cantwell and Piscitello (2004) focus on knowledge seeking R&D. They hypothesize that multinational firms may locate their R&D so as to avail themselves of localized intra-industry, inter-industry or public sector knowledge spillovers. They find, first, that localized inter-industry knowledge spillovers are important in attracting R&D operations of multinationals. The authors take this first finding to imply that local concentrations of general industrial technological expertise is as important as specialized (industry-specific) expertise in attracting foreign R&D operations. The locational advantages involved may flow from agglomeration economies (deep input markets and availability of specialized inputs). Second, they find that intra-industry knowledge spillovers also attract multinational R&D operations provided these spillovers emanate from the local operations of other multinationals rather than from a strong and longstanding domestic industry. Third, they find that knowledge spillovers from public sector research organizations attract foreign controlled R&D operations but that these spillovers are not highly localized. The authors take this third finding to imply that geographic proximity is more important in facilitating inter-company knowledge spillovers than in facilitating the acquisition of knowledge from public sector research institutions (2004, pp.20-21).

6.3 Implications of the internationalization of R&D activities by multinational enterprises.

The R&D operations of multinational enterprises are decentralizing but the process is a gradual one, much of which has been intra-European. The extent and nature of the decentralization that has occurred varies from industry to industry. The most important motive for R&D decentralization has been, and may continue to be the need to respond to unique demand or production conditions in important foreign markets. An emerging and much discussed motive for decentralization is to access specialized local expertise and facilities and localized knowledge spillovers. While this bears further investigation, it is not clear that, in aggregate at least, R&D has been decentralized more rapidly

than production, marketing and other functions. Intriguing as it has been for scholars, knowledge-seeking and knowledge-augmenting R&D decentralization may not have been quantitatively important to date.

The implications of the international decentralization of R&D for Canada are somewhat mixed. The hope appears to have been that R&D decentralization would increase the R&D-intensity of the relatively large community of foreign owned firms in Canada thereby increasing aggregate BERD-intensity in Canada and improving BERD-intensity ranking internationally. To the extent that R&D decentralization is required to support production or sales in large foreign markets with unique demand or production characteristics, it would appear unlikely to result in additional decentralization toward Canada. Indeed, its most visible effect would probably be to increase the degree to which the R&D operations of Canadian-based multinationals are decentralized internationally.

To the extent that R&D decentralization is knowledge-seeking or knowledge-augmenting in nature, decentralization in favour of Canada may occur in some cases. Optimism in this regard might be tempered by a number of considerations. First, the R&D involved may be more of the listening-post variety, drawing from the local knowledge pool but not contributing to it. Second, jurisdictional competition among advanced, knowledge-intensive regions and economies for partially footloose R&D operations is likely to be intense. Decentralization has been most prominent within the European Community and, more recently to the United States. Third, the human capital in which local knowledge pools reside not only walks out the door at the end of the day, it is potentially highly mobile internationally. The problem in this regard is the familiar one of attracting and retaining highly qualified personnel.

While this discussion has focused on the decentralization of R&D within multinational enterprises, this is not the only form of international decentralization and it may not be the most important one in the future. The information technology revolution has facilitated the outsourcing of a variety of functions formerly thought to be strictly internal to the firm. This development has been most prominent in the electronics, pharmaceuticals and commercial aircraft industries.[14] In this regard, it might be more appropriate for both researchers and policy-makers to focus their attention on the trade in R&D services.

7. Possible Effects of Industry Structure and Ownership on BERD Intensity and innovation in Canada

BERD intensity depends on industry R&D-intensities and industry mix effects. The relatively low R&D intensities of the motor vehicle manufacturing industry and the Service sector, along with the relatively small size of the most R&D-

---

[14] "Outsourcing Innovation" Business Week (March 21, 2005) http://www.businessweek.com/magazine/content/05_12/b3925601.htm

intensive industries explain most of the BERD-intensity gap between the United States and Canada. Canada's BERD-intensity would look much better internationally if the motor vehicle manufacturing industry were ignored. No doubt, other countries could make claims for similar exceptions.

A natural reaction of those concerned with increasing BERD-intensity for its own sake might be to attempt by one means or another, to induce motor vehicle manufacturers to relocate R&D to Canada. Whether this is remotely practical is questionable. North American automotive R&D is highly concentrated in the state of Michigan. Other states have attracted relatively little. Agglomeration economies must matter and it may take a great deal to offset them. As well, Canadian governments have historically used whatever inducements and leverage they had at hand to "bargain" for automotive manufacturing jobs. Unless Canadian governments have unused bargaining power (which seems unlikely), bargaining for a bigger share of R&D jobs implies sacrificing something else. To what end? Canadian plants presumably benefit in full now from R&D done by affiliated companies in Michigan and elsewhere. It is hard to imagine that relocation of some of this R&D would make the remaining Canadian facilities any more productive or technologically progressive than they now are. It is questionable whether changing the focus of locational bargaining from manufacturing to automotive R&D jobs would do anything other than raise the measured BERD, if that.

Industry effects are very important in explaining R&D-intensities and it is clear that to the extent possible, econometric analysis should attempt to estimate as many parameters as possible at the industry level. The finding that some Canadian firms and industries are innovative (as these things are measured) by world standards does not imply that public policy should be industry specific. Indeed, the policies that would encourage the growth in the number of innovative firms are quite general – open markets, free capital movement, competitive taxation and smart regulation.

The econometric evidence on the relationship between industry structure, firm size and ownership on one hand and R&D-intensity on the other is far from definitive. This is not the fault of those who have attempted to investigate this issue although they might show a little more humility when it comes to drawing conclusions. It appears to be the case that size and ownership effects interact and vary across industries. Moreover, R&D-intensity may take a considerable period of time to adjust to the effects of changes in size, ownership and industry structure. As well, factors such as export intensity which are often viewed as causal (exogenous) in these studies are, in fact, jointly dependent (endogenous).

While the appropriate methodology is to disaggregate and allow for both inter-temporal adjustment lags and the endogeneity of some explanatory variables, the relatively thin nature of the set of business R&D performers in Canada can result in small sample sizes and results that are sensitive to the presence or

absence of a few large firms. The "Catch 22" is that attempts to use econometric analysis to investigate the reasons for the relative thinness of the set of business R&D performers in Canada is frustrated by the thinness of the set of business R&D performers itself.

Despite the attention paid to it over the years, the basis for the relationship between firm size and R&D-intensity is not well understood. Firm size is thought to be a proxy for a number of factors including economies of scale in the R&D function and the advantages of internal exploitation of new technologies. Financial, vintage and intellectual property explanations have also been suggested. The role played by these and other possible explanatory factors is likely to vary across firm sizes and from industry to industry.

Perhaps because of the necessarily naïve specification of the models, the relationship between size and R&D spending has not been measured with precision. If the elasticity of R&D spending with respect to firm size among R&D performers is one as the international evidence suggests, then R&D-intensity does not change with firm size and an absence of very large firms in Canada cannot be an explanation for Canada's relatively low BERD-intensity. If the threshold size at which a firm becomes an R&D performer is indeed "modest" as the international evidence is said to suggest then the likelihood that Canada has a greater proportion of firms below the minimum size threshold than comparator countries is also reduced as is the likelihood that firm size is an explanation for Canada's low BERD-intensity. Of course, Canada could still have a disproportionately large number of firms below even a modest threshold or the threshold could be higher in Canada or (contrary to the Canadian evidence) the size elasticity among performers could exceed one in Canada. The point is that the absence of very large firms and the presence of a disproportionately large number of very small firms are two very different explanations for a low BERD-intensity. It does not appear at present that it is known whether either, neither or both of these explanations have any traction.

A reasonable interpretation of the existing Canadian evidence on the effect of foreign ownership on R&D intensity is that, given their size and the industry in which they operate, foreign controlled firms are more likely to perform R&D and, may be more R&D-intensive as purely domestic firms. Foreign controlled firms are less likely to perform R&D locally than domestically controlled multinationals and they may be less R&D-intensive. Foreign ownership "explains" Canada's low BERD-intensity only in the trivial sense that BERD-intensity would ultimately be higher if the foreign owned firms in Canada were parents rather than subsidiaries.

Given size and industry effects, foreign controlled firms are also more likely to introduce product or process innovations in Canada than are purely domestic firms but are less likely to do so than domestic multinationals. As far as manufacturing technology, productivity and productivity growth are concerned

foreign owned firms perform at least as well as their domestic counterparts. The essential point is that although foreign subsidiaries are generally less R&D-intensive than their parents, in other perhaps more relevant dimensions they perform at or above host economy standards. They are not truncated in the sense of ignoring productive innovative opportunities in the host economy due to lack of information or arbitrary head office policies.

The implication of this conclusion is that foreign owned firms in Canada will not suddenly "see the light" and increase their local R&D-intensity. They already see the light. They would presumably be responsive to any new domestic incentives if it were deemed beneficial to the host economy to offer them. Affiliates may experience an increase in their R&D-intensity as a consequence of the general global decentralization of R&D activity. Whether Canadian affiliates can expect to participate in this decentralization in a significant way is a matter of some doubt. In any event, the policies that would attract additional R&D to Canada are the same ones Canada would want to pursue to encourage investment in innovation in general (see below).

While national economies can be successful without a complement of large, indigenous R&D performing firms, the ongoing existence of such firms provides an indication that the domestic environment is conducive to innovation. It is on this environment rather than on the operations, structure or ownership of firms themselves that policy concerns should be focused.

7.1. Implications for public policy

Policy responses to Canada's relatively low BERD-intensity ultimately converge on three types of policies: getting more bang for a buck by increasing the utilization (commercialization) of R&D that is already occurring; (2) increasing the R&D-intensity of existing R&D performers, either foreign or domestic and; (3) encouraging the emergence and expansion of additional R&D performers both foreign and domestically owned.

The principal virtue of a policy emphasis on the commercialization of R&D is to take the focus off R&D spending per se. While formal R&D is central to the innovative process it is not always necessary and it is certainly not sufficient. R&D and commercialization require different sets of skills. If the goal is actually to encourage innovation rather than simply increasing Canada's BERD-intensity, then a wider set of issues must be addressed. The concern in this regard is that while there may be a relatively small number of significant R&D performers in Canada, there may be an even smaller number of firms with the requisite co-specialized assets (technological, production, market and managerial knowledge). Hence the Conference Board's concern with encouraging the growth of "anchor tenants," firms with the capability of both performing and utilizing R&D.

A policy focus on commercialization is, however, not without problems. The first is that commercialization is an amorphous concept that does not admit well to measurement. Knowledge can be exploited economically in many ways. The innovative process is cumulative and interactive. Some knowledge may not be exploited commercially itself but instead serve as the basis for future R&D which ultimately results in innovations that are profitable. Some innovations or pieces of knowledge may yield a return as a result of being traded to other firms in return for other information or rights to use it. It is for these reasons that the most credible conclusions regarding commercialization are derived from historic case studies. Students of the history of technology tell us that a great deal of innovation is the accumulation of small, unremarkable process improvements. These are commercialized in the sense that they reduce the costs and increase the profits of the firms that make them. They are part of an ongoing process. They may not be announced or even be countable. This form of innovation may be more typical of firms in small market economies such as Canada.

A second problem with commercialization as a policy objective is that it is redundant for the business sector and may not be appropriate for the other R&D-performing sectors of the economy. The business sector is already profit-oriented and if it is not, lectures from the government will not make it so. For the academic, government and non-profit sectors, commercialization may not be appropriate as an overriding goal. It is, of course, desirable that public sector R&D organizations be well-managed and that their R&D be of value to the national economy. This may or may not involve commercialization as it is conventionally measured.

With regard to the academic sector, it is again desirable that the business and academic sectors interact. To this end there have been considerable investments in technology transfer offices, incubators and research parks. It might also been argued that the focus on deriving a direct commercial payoff from university research in the form of patents, royalties or spin-off businesses, is misplaced. Commercialization is a much broader concept than the transfer of discrete, proprietary technologies. Commercialization occurs when students graduate and go to work in business firms or when students are employed in business in coop programs or when university faculty and business personnel are interchanges or when commercial users access what has come to be known as open science. Moreover, focusing on developing technologies of immediate commercial value not only diverts the university from its primary mandate but is also potentially destructive of the free interchange of ideas which is intrinsic to basic research.

The attraction and retention of foreign-owned R&D performers has been discussed by Head and Ries (2004) in the context of a discussion about attracting and retaining high value added activities in general. Head and Ries conclude that while the effect is difficult to measure precisely, the evidence is that

foreign direct investment (FDI) could be very sensitive to international differences in business taxation. The attraction of FDI could bring with it the type of affiliate R&D that is necessary to support local production and to respond to special characteristics of local markets. Insofar as the evidence of the effect of international differences in business taxes on the R&D location decision itself is concerned, Head and Ries find that what little evidence there is implies that lower host country taxes might attract additional R&D to the host country (2004, p.18).

Personal taxation may also matter. The highly educated personnel required to staff an R&D operation (whether domestically owned or foreign owned) are also internationally mobile and Head and Ries cite evidence to the effect that their migration decisions (especially among the young) are potentially sensitive to international tax differences but they do not see this as a major issue for Canada (p.19).

Head and Ries also survey the evidence with respect to locational subsidies (investment promotion). They find that investment promotion can affect locational decisions although a great deal of this evidence comes from within the United States where issues of differential market access and national economic characteristics were not at play. Locational subsidies also appear to have a greater impact where the flow of new investment is large relative to the stock, that is (for example, the relocation of automobile assembly from Japan to North America by Japanese producers). Even here, locational subsidies may simply offset each other.

The Head and Ries study also notes that unless they attract investment to areas of chronic underemployment, these subsidies simply bid resources away from other (possibly higher valued, but unsubsidized) uses. Moreover, the regions that are attractive locations for investors (especially high tech investors) because of the agglomeration economies they offer typically do not have much in the way of an unemployment problem (2004, p.21). That Canadian subsidies to business have often been at odds with the realization of agglomeration economies was emphasized by Michael Porter in his 1990 *Canada at the Crossroads* study.

Governments may also attract R&D performers from abroad by promoting what have become known as innovative clusters. R&D performers are attracted to a degree by locations with deep markets for specialized human capital and other input suppliers as well as by the presences of other R&D performers (not necessarily in the same industry) from whom they can learn. Globerman (2001) observes that successful clusters are often composed of dense networks of small and medium sized firms. He cautions against government policies that attempt to build up a few large national champions. Instead, he supports general R&D incentives and government support of collaborating public sector institutions such as universities. Globerman recommends that

> governments should focus less on industrial policy, whereby they target "desirable" industries or "national champions," and instead encourage clusters by promoting conditions within regions that contribute to the realization of external economies.(2001, p.ii)

With respect to general measures to encourage business R&D spending, all commentators cite the role of market size. It is not only the greater propensity of larger firms to engage in R&D that matter, it is the role of larger markets in supporting specialized human capital (technical and managerial), specialized input suppliers and specialized financial institutions. In this regard it is absolutely essential that firms located in Canada have dependable access to larger foreign markets, not only for their products but also for financial services and specialized employees and managers.

With respect to government R&D incentives to business, both Head and Ries (2004) and Harris (2005) are sceptical about R&D tax credits. They argue that Canada's R&D tax regime has long been among the more generous in the world but this does not appear to have helped Canada's BERD-intensity ranking. Of course, without the tax credit Canada's BERD-intensity would, on the evidence, probably be even lower. It is also the case that the response to a tax credit or any other government incentive depends on the opportunities and capabilities of the firms involved. If the broader tax, regulatory, trade and financial environment is not conducive to innovation, neither R&D tax credits nor subsidies are going to fix this. In this regard, business taxation in Canada is viewed as being uncompetitive internationally by some experts (Chen and Mintz, 2005). Harris (2005) argues that the complementarities between capital investment and R&D are such that matching the general level of business taxation in the United States could have a strong positive effect on business R&D spending in Canada.

Harris (2005) also favours making greater use of business R&D subsidies. To reduce the manifest political economy problems that have been associated with business subsidies at the federal level, he suggests that they be administered provincially. He also argues that since the potential for realization of agglomeration economies is relatively high in Alberta and British Columbia and business R&D intensity is relatively low in these provinces, the proposed R&D subsidies should be confined to these provinces.

In response to this proposal, it might be noted that Canada has had a regime of R&D subsidies (IRAP and the Defence Industries Productivity Program, now Technology Partnerships Canada) in place for at least as long as it has had R&D tax incentives. If R&D tax credits are judged to have failed on the basis of Canada's low BERD-intensity ranking, these subsidy programs would presumably be judged the same way. Insofar as firm-specific provincial R&D subsidies are concerned, issues of duplicate bureaucracies and inter-provincial cannibalization come to mind in addition to the usual issues associated with

targeted business subsidies. As far as Alberta is concerned, those who are distressed that an improved toaster has not been invented in Alberta might wish to investigate the ex post return to the province on the resources it devoted to improving oil sands extraction technologies.

8. Conclusions and Suggestions for Further Research

Canada's BERD-intensity is relatively low by international standards. While this need not imply that the rate of innovation is relatively low in Canada, some other indicators of innovative output also tend to point in that direction. This conclusion remains somewhat tentative, however, as the nature and process of innovation in Canadian industry remain poorly understood. Much more work of an interdisciplinary nature needs to be done on this subject.[15]

There are some structural explanations for Canada's low BERD-intensity but these are perhaps wearing a little thin after forty years. While it is true that the low R&D-intensity of a very large Canadian industry, motor vehicle manufacturing, drags Canada's BERD-intensity down, it is also true that some high-tech industries are relatively smaller in Canada than in comparator countries and some medium-tech industries are less R&D-intensive. Some service industries also appear to be less R&D-intensive in Canada than in the U.S. and research into the source of this difference would be instructive.

Structural explanations for Canada's relatively low BERD-intensity may have to go deeper. Some structural factors may such as geographic location, distance and population density may be immutable. Others, such as access to international product, capital and skills and knowledge markets can be made more favourable by public policy but continuing effort is required. Innovation is, in essence, an act of entrepreneurship. Typical indicators of a country's knowledge capital are stocks and flows of science and engineering graduates. This is a bare beginning. Where do entrepreneurs come from? How do managers of entrepreneurial organizations obtain the requisite training and experience? Policy-makers might want to understand these things better.

In the same vein, the continued appeal to firm size as a structural factor is not entirely persuasive. The evidence on the relationship between firm size and R&D-intensity implies that it is not the size of the larger firms that matters for BERD-intensity, it is the size distribution of the smaller firms. This begs the question of what the size threshold at which a firm begins to engage in R&D is and why Canada apparently has a disproportionate number of firms below this threshold.

---

[15] The work of Baldwin and Gu (2004a) on the effect of plant turnover on manufacturing productivity growth is important in this regard. It might be possible to build on this work to determine the nature of the differences between new plant and old plants that make the former more productive.

Encouraging innovation requires that corporate and personal taxation and regulatory structures be internationally competitive. This does not imply a race to the bottom. It does require value for money in public services. This requires ongoing benchmarking as well as continued research into the attributes that have the greatest locational impact.

Increasing GERD-intensity is relatively simple. A government interested in GERD-intensity for its own sake can simply spend more money on R&D. Increasing BERD-intensity is more difficult. Businesses have to find it profitable to spend more on R&D. Some have suggested what they think would be a quick fix in the form of replacing R&D tax credits with direct subsidies. Although there may be some merit in revisiting the evidence in this regard, there is presently little or nothing to indicate that firms are more responsive to subsidies than to tax credits or that firm-specific subsidies would result in more productive R&D investments.

Despite its prominence in discussions of Canada's low BERD-intensity, foreign ownership is a side issue. Attempts for force relocation of R&D to Canada are bound to be counterproductive. Insofar as the trend towards the internationalization of R&D is concerned, there are some interesting research questions. While there has been much academic discussion, the evidence as to whether R&D has, in fact, decentralized relative to production and if so under what circumstances appears rather slim. Whether decentralization will even involve affiliates to any great degree in the future what effect any of this might have on Canada are also interesting research topics.

References

ab Iorwerth, Aled (2005), "Canada's Low Business R&D Intensity: the Role of Industry Composition" (Ottawa, Department of Finance Working Paper 2005-03)

Acheson, Keith (1989) "Power Steering The Canadian Automotive Industry" Journal of Economic Behavior and Organization I I, pp. 237-251.

Baldwin, John and Petr Hanel, (2003) Innovation and Knowledge Creation in an Open Economy (Cambridge, Cambridge UP)

Baldwin, John and Wulong Gu (2004) "Multinationals, Foreign Ownership and Productivity Growth in Canadian Manufacturing", forthcoming in Chen, Z. and M. Duhamel (Eds.), Industrial Economics and Performance in Canada, Industry Canada Research Volume Series, Calgary, AB: University of Calgary Press.

Baldwin, John and Wulong Gu (2004a) "Industrial Competition, Shifts in Market Share and Productivity Growth" (Ottawa, Statistics Canada, Economic Analysis and Research Paper series, No.21)

Becker, Bettina and Nigel Pain (2003) "What Determines Industrial R&D Expenditure in the UK?" (National Institute of Economic and Social Research, Discussion Paper 211, April)

Blomstrom, Magnus and Ari Kokko (2003), "The Economics of Foreign Direct Investment Incentives" (NBER Working Paper No. 9489, February)

Cantwell, John and Lucia Piscitello (2004), "Recent Location of Foreign-Owned R&D Activities by Large MNC's in the European Regions: The Role of Spillovers and Externalities" (Rutgers Business School)

Chen, Duanjie and Jack Mintz (2005), "Federal Corporate Tax Cuts Would Lift Canada's Standard of Living" (C.D. Howe Institute, April)

Cohen, Wesley and Steven Klepper (1996), "A Reprise of Size and R&D" Economic Journal 106 (July) pp.925-51.

Conference Board of Canada (2004), Exploring Canada's Innovation Character: Benchmarking Against Global Best (Ottawa)

Globerman, Steven (2001), "The Location of Higher Value Added Activities" (Industry Canada, Occasional Paper No. 21, 2001)

Ebersberger, Berndt and Hans Loof (2005), "Innovation Behavior and Productivity Performance in the Nordic Region: Does Foreign Ownership Matter?" (paper presented at the 4th European Meeting on Applied Evolutionary

Economics, University of Utrecht)
http://econ.geog.uu.nl/emaee/14_ebersberger.pdf

Hakanson, Lars and Robert Nobel "Determinants of foreign R&D in Swedish multinationals" Research Policy 22, (1993) pp.397-411.

Harris, Richard (2005), "Canada's R&D Deficit and How to Fix it" (C. D. Howe Institute, Commentary No.211, May)

Head, Keith and John Ries (2004), "Making Canada the Destination of Choice for Internationally Mobile Resources," (Industry Canada, Discussion Paper No.14, 2004)

Holbrook, J. A. D., and R. J. Squires (1996), "Firm-level analysis of determinants of Canadian industrial R&D performance" Science and Public Policy (December), pp.369-74.

Keller, W., and S. Yeaple (2003) "Multinational Enterprises, International Trade and Productivity Growth: Firm Level Evidence from the United States" (Cambridge, NBER Working Paper 9504)

Kumar, N. (2001), "Determinants of location of overseas R&D activity of multinational enterprises: the case of US and Japanese corporations" Research Policy 30, pp.159-174

Le Bas, C. and C. Sierra (2002) Location versus home country advantages in R&D activities: some further results on multinationals' locational strategies, Research Policy 31 (2002), pp.589-609.

Link, Albert, Terry Seaks and Sabrina Woodbery (1988), "Firm size and R&D Spending: Testing for Functional Form" Southern Economic Journal 54 pp.1027-1032.

Mataloni, Raymond (2005), "U.S. Multinational Companies: Operations in 2003" Survey of Current Business (July) pp.9-29
http://www.bea.gov/bea/ARTICLES/2005/07July/0705_MNCs.pdf

Moris, Francisco (2004) "Industrial R&D Employment and in U.S. Multinational Corporations" Infobrief (NSF 05-302, December)
http://www.nsf.gov/statistics/infbrief/nsf05302/

OECD (2005), Science, Technology and Industry Outlook 2004, "Multinational Enterprises and Productivity Growth: Insight at the Firm Level" (Paris) Ch.6.

Pilat, Dirk (2005) "Canada's Productivity Performance in International Perspective" International Productivity Monitor 10 (Spring) pp.24-44.

Sharpe, Andrew and Olivier Guilbaud (2005), "Indicators of Innovation in Canadian Natural Resource Industries" (Ottawa, CSLS Research Report 2005-03) http://www.csls.ca/reports/csls2005-03.pdf

von Zedtwitz, Maximilian and Oliver Gassmann (2002), "Market versus technology drive in R&D internationalization: four different patterns of managing research and development" Research Policy 31, pp.569-588